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SHALLOW WATER ACOUSTIC STUDIES.(U)

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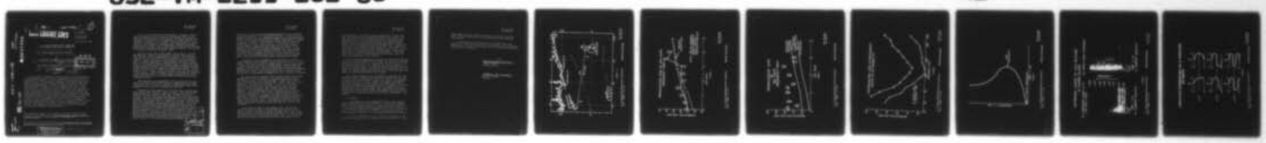

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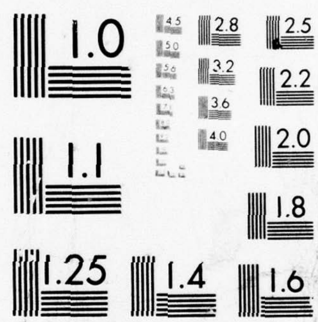


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U. S. NAVY UNDERWATER SOUND LABORATORY
FORT TRUMBULL, NEW LONDON, CONNECTICUT

# SHALLOW WATER ACOUSTIC STUDIES[1]

by

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USL-TM-

USL Technical Memorandum 2211-282-68

27 November 1968



13 p.

ABSTRACT[2]

In an attempt to formulate an accurate model for sound propagation in shallow water, several tests were conducted in Long Island Sound. A bottom-mounted projector, located off Block Island, and explosives were used as sources. A bottom-mounted hydrophone off Fishers Island and a hydrophone suspended over the side of a ship stationed near Watch Hill Point served as receivers. The latter hydrophone was used at three different depths. Propagation loss was measured over the two paths and plotted as a function of sea state. The results were compared with current shallow-water prediction equations. Data obtained during the winter agreed fairly well, while data obtained during the spring showed considerably higher loss than predicted. This discrepancy is attributed to the many more bottom bounces than predicted by the shallow-water formulas. A plot of propagation loss as a function of frequency for explosive sources showed a minimum at 140 Hz. Missilyzer analysis of the same data indicated that the lowest normal mode predominates in this channel. This conclusion was borne out by an analysis of propagation loss curves for different receiving depths.

1
This memorandum consists of the abstract, text and slides of a paper presented by the authors at the Seventy-Sixth Meeting of the Acoustical Society of America in Cleveland Ohio on 19 November 1968.

2
This abstract was previously published in The Program of the Seventy-Sixth Meeting of the Acoustical Society of America, Cleveland, Ohio 19-22 Nov 68.

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The U. S. Navy Underwater Sound Laboratory is engaged in shallow water investigations for the purpose of formulating a more accurate model for sound propagation in this medium. The current shallow water propagation equations have not yielded accurate enough predictions in all cases. In addition, it is planned in the current tests to include studies of such parmaters as frequency smear, time smear and normal mode operation in order to get a better picture of the factors affecting shallow water propagation and of their temporal stability. What follows is a report on the results obtained to date.

For most of the tests the BIFI Range, shown in Fig. 1, was used. The range has a length of approximately 19 nautical miles and has a depth of about 120 feet through most of its extent. At Block Island, a projector tuned at 1700 Hz is bottom mounted at a 55 foot depth at point S. Several hydrophones are bottom mounted near Fishers Island. The one currently being used is bottom mounted in 155 feet of water at point H. The receiving station at Fishers Island is connected by means of data transmission lines to the Data Acquisition and Reduction Center at the Laboratory where the signals are recorded and analyzed. The Laboratory is located about 7 miles from Fishers Island near the northwest corner of Fig. 1. Several frequency sensitive reed relays are connected in the receiving circuits at Fishers Island, and these permit remote control and calibration of the system from the Laboratory via the data transmission lines.

Some propagation loss measurements were also conducted over paths from Block Island to Watch Hill Point and to Weekeapaug Point, respectively, shown near the top of the figure. In these cases, hydrophones suspended over the side of an anchored ship were used.

Propagation loss measurements at 1700 Hz have been conducted twice daily over the BIFI range for a number of months. Sea state and wind speed readings were obtained in each case. In addition, velocity profiles at several points along the range were also obtained on several occasions. For each transmission the propagation loss was computed and averages obtained were plotted as a function of sea state and wind speed. Fig. 2 shows propagation loss as a function of sea state. It shows the results for measurements made during the months January to April 1966 when the velocity profile varied approximately from a weak positive gradient forming a half channel to an essentially isovelocity condition. The encircled numbers above each point show the respective numbers of signals averaged in each case. The points are joined by a solid line to help locate them. The dashed curves in the slide show the minimum and maximum losses predicted by the present shallow water prediction formula. The measured values agree fairly well with the predicted values. Fig. 3 shows a similar set of values obtained during the months April to June

1966 when the velocity profile varied approximately from an essentially isovelocity condition to a strong negative gradient. In this case, the average measured values are considerably higher than the maximum predicted values. It should also be noted that no definite dependence on sea state is apparent. Comparable tests performed in June, July and August 1967 showed results similar to those of Fig. 3. In an attempt to resolve this discrepancy, several rays were traced over the range under the negative velocity gradients existing during the warm months. It was found that the acoustic ray suffered considerably more bottom bounces than predicted by the present prediction formula. This would account for both the high propagation loss and for lack of dependence on sea state. The results presented here as well as others not yet analyzed, will be used to modify the present shallow water prediction formula.

In addition to the CW propagation loss measurements at 1700 Hz, other measurements were conducted in which explosives were used for sound sources. These tests were done for three reasons. First, it was desired to conduct dispersion analysis to determine which modes propagated the length of the BIFI range. Second, it was desired to measure amplitude dependence as a function of depth and compare the result with that predicted by normal mode theory. Third, explosives provided a convenient broad-band source for measurements of propagation loss as a function of frequency.

The signals from the explosives were recorded broad band and passed through logit filters for analysis. The results are shown in Fig. 4. Two curves are shown. One is for data taken in August 1967 and the other is for data obtained in January 1968. As may be seen, both these curves show a minimum loss in the range 100 - 150 Hz. The shapes obtained for many other shots were very consistent with those shown here. To explain the shape of these curves, we consider the main components of the propagation loss at the frequencies in question. These are: shear and absorption losses in the bottom and scattering losses at the boundaries. The first two components decrease with increasing frequency and with angle of incidence relative to the normal. This causes a decrease in propagation loss with increasing frequency which is apparent below 100 Hz. At frequencies above about 100 Hz, it appears that scattering losses at the boundaries, which increase with increasing frequency, become relatively more important than the first two effects.

To get further insight to what happens in this sound channel, a dispersion analysis by means of the Kay Missilyzer was done on the signals received from explosive sources in January 1968. These curves show frequency as a function of time and the shape of the curve provides interesting information concerning the signal. Fig. 5 is a sketch of a theoretical dispersion curve, showing both the Airy frequency and the cutoff frequency. The values of these frequencies for a given broad band signal may be used to determine the "modes" which exist in the wave in question. Two actual dispersion curves for one of the shots are shown in Fig. 6. The curve at the left is the dispersion curve obtained after the signal has been passed through a 55 Hz low-pass filter. The one at the right is for a broad band signal. This latter trace curves to the right from about 120 Hz down. Close scrutiny of the trace at the left shows the Airy frequency to be at 40 Hz. In both cases, the cutoff frequency is seen to be below 30 Hz. Calculations showed that for the BIFI channel the cutoff frequency for the lowest mode is 20.8 Hz while for the second mode it is 62.4 Hz. Thus, the lowest mode predominates in this channel.

To test the above conclusions, an analysis was done of the expected variation of signal amplitude with water depth for the first three modes. The curves are shown in Fig. 7. The curves on the left are for the cutoff frequency while those at the right are for infinite frequency. It should be noted that for n = 1, the lowest mode, the amplitudes near the surface and near the middle of the channel do not change much with frequency. The maximum change occurs near the bottom. For other modes, the changes of amplitude with depth are more complex.

Fig. 8 shows propagation loss as a function of frequency for three different depths as obtained from a hydrophone suspended over the side of a ship anchored near Watch Hill Point. Also shown is the amplitude distribution of the first mode. Comparing the change in propagation loss with frequency for the three cases, we see that between 150 Hz (the lowest frequency for which values at all three depths are available) and 800 Hz, the two shallower depths shown little change, while the deepest signal shows a larger change. Also, propagation loss measured at mid-depth is lower than at the two other depths. These results are consistent with the conclusion that the lowest mode predominates in this channel.

To summarize:

1. Propagation loss at a frequency of 1700 Hz has been measured under a large variety of thermal conditions, and the results compared with the present prediction formula. It was found that the theoretical formula does not predict adquately propagation loss under conditions of strong negative gradients. It appears that the formula does not take into account fully the increase in bottom loss caused by a negative velocity gradient relative to loss measured under isovelocity conditions.

2. A plot of propagation loss as a function of frequency showed a minimum of propagation loss at a frequency of approximately 100 - 150 Hz

during summer and winter thermal conditions. This result, which has been a commonly observed shallow water phenomenon has been explained theoretically.

3. It was found that the propagation of discrete modes occurs over the BIFI range and that the first mode predominates. The amplitude dependence as a function of depth agrees well with theoretical predictions for this type of propagation.

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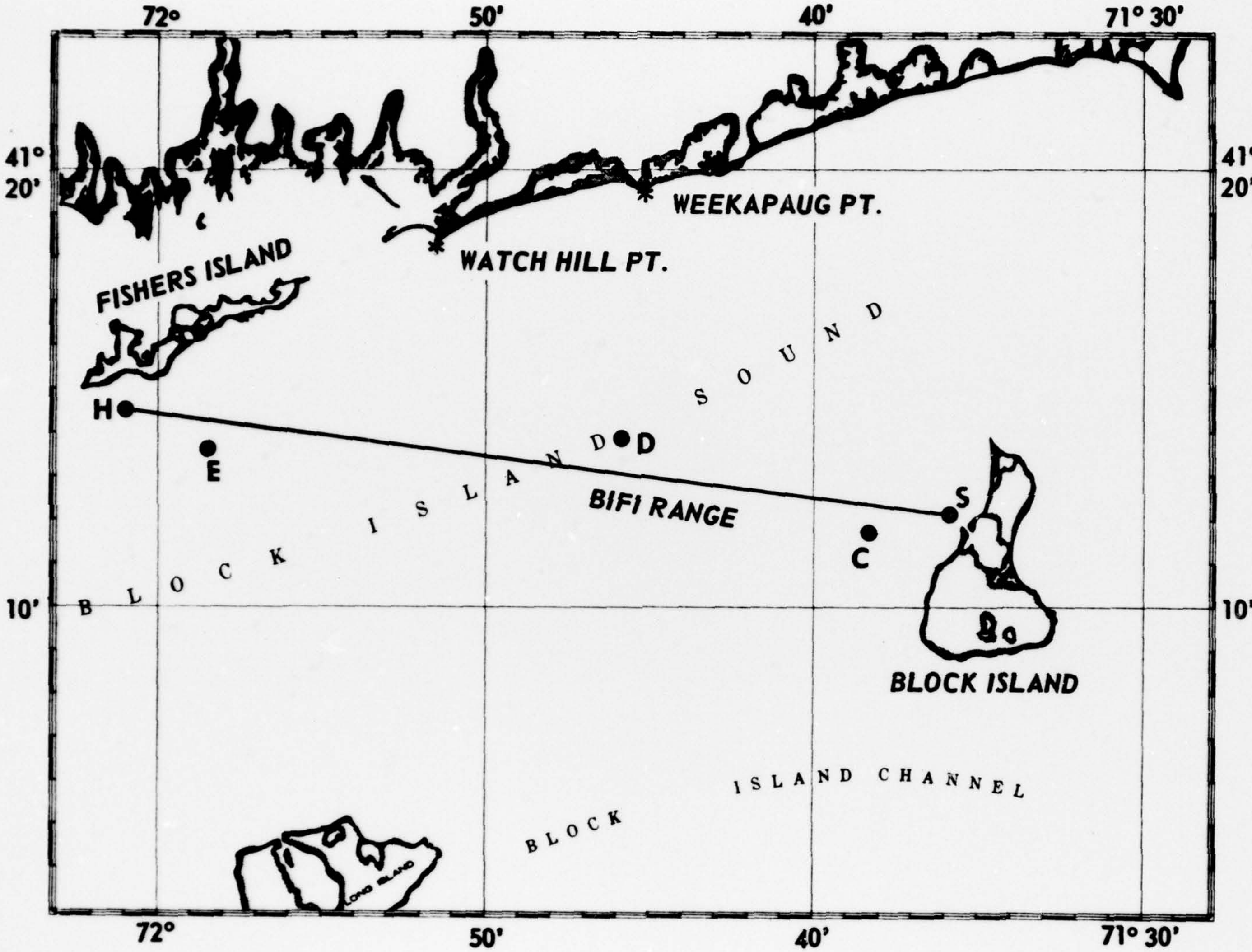


FIGURE 1

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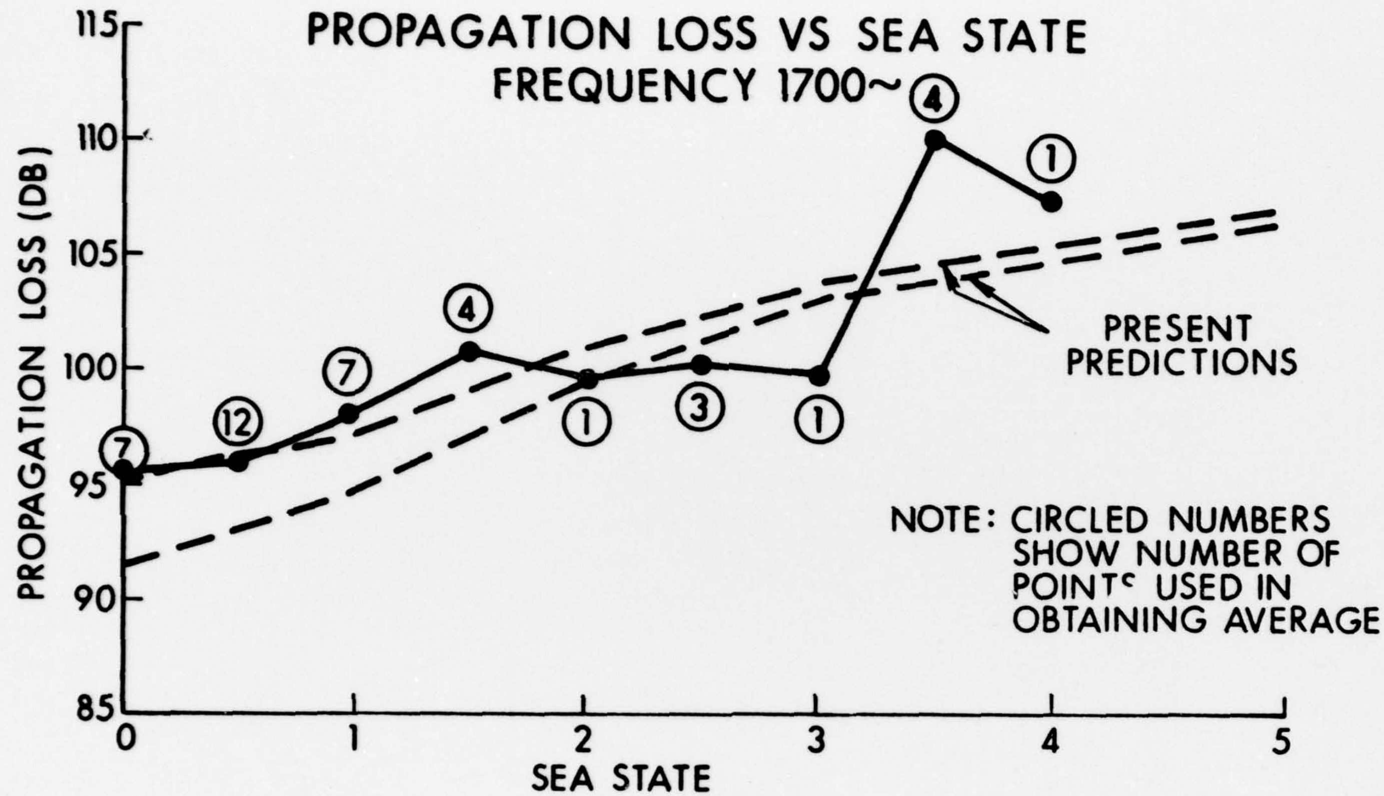


FIGURE 2

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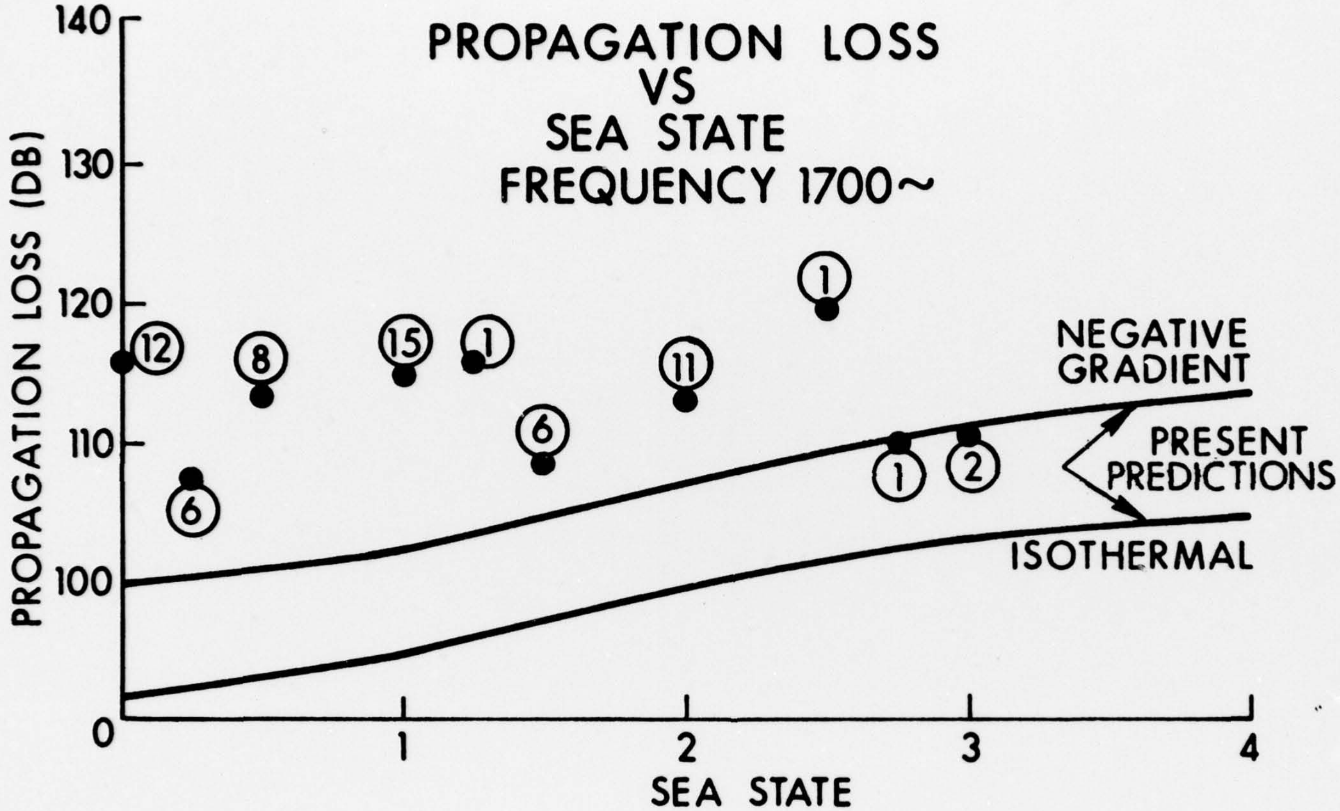


FIGURE 3

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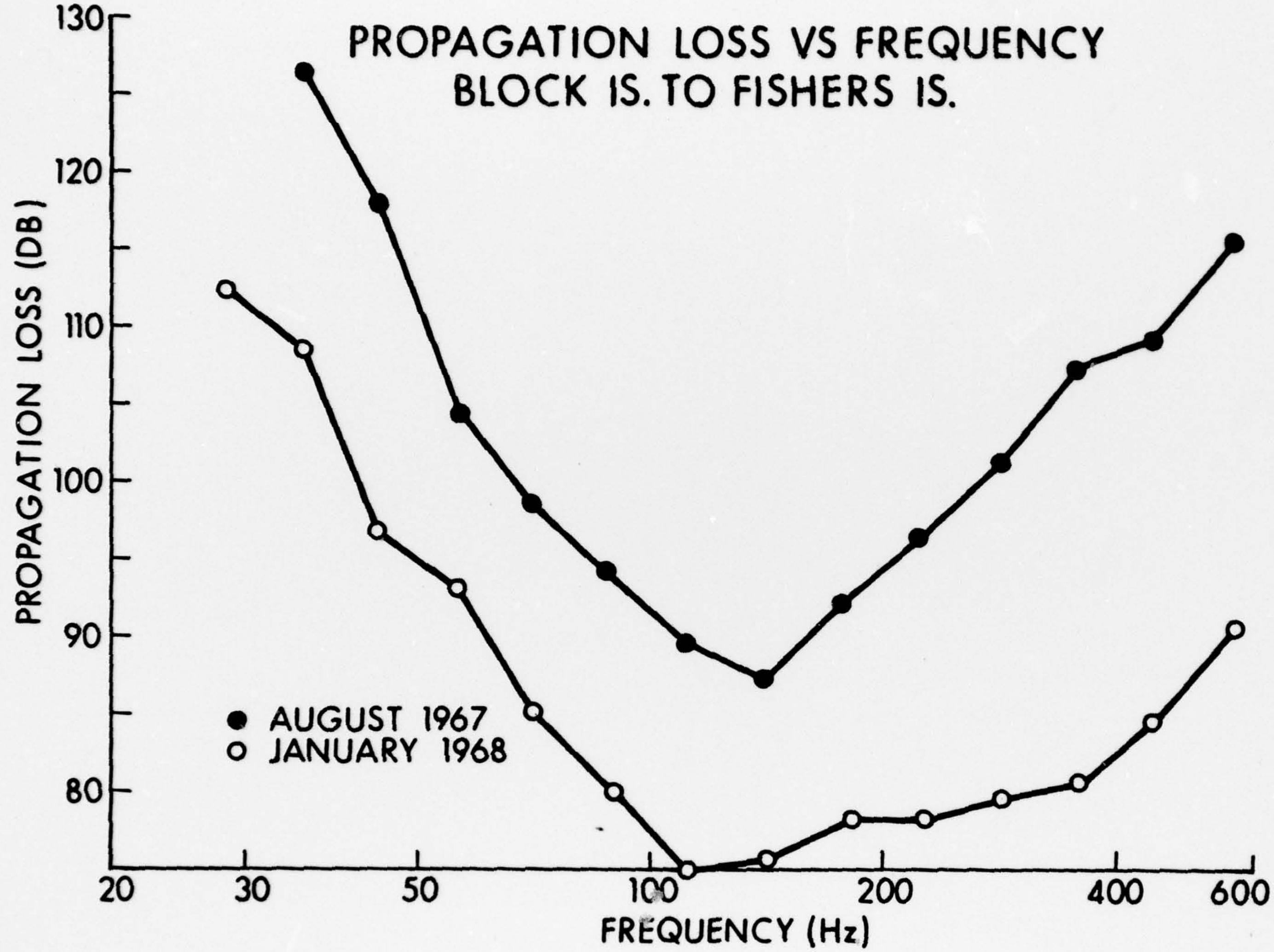


FIGURE 4

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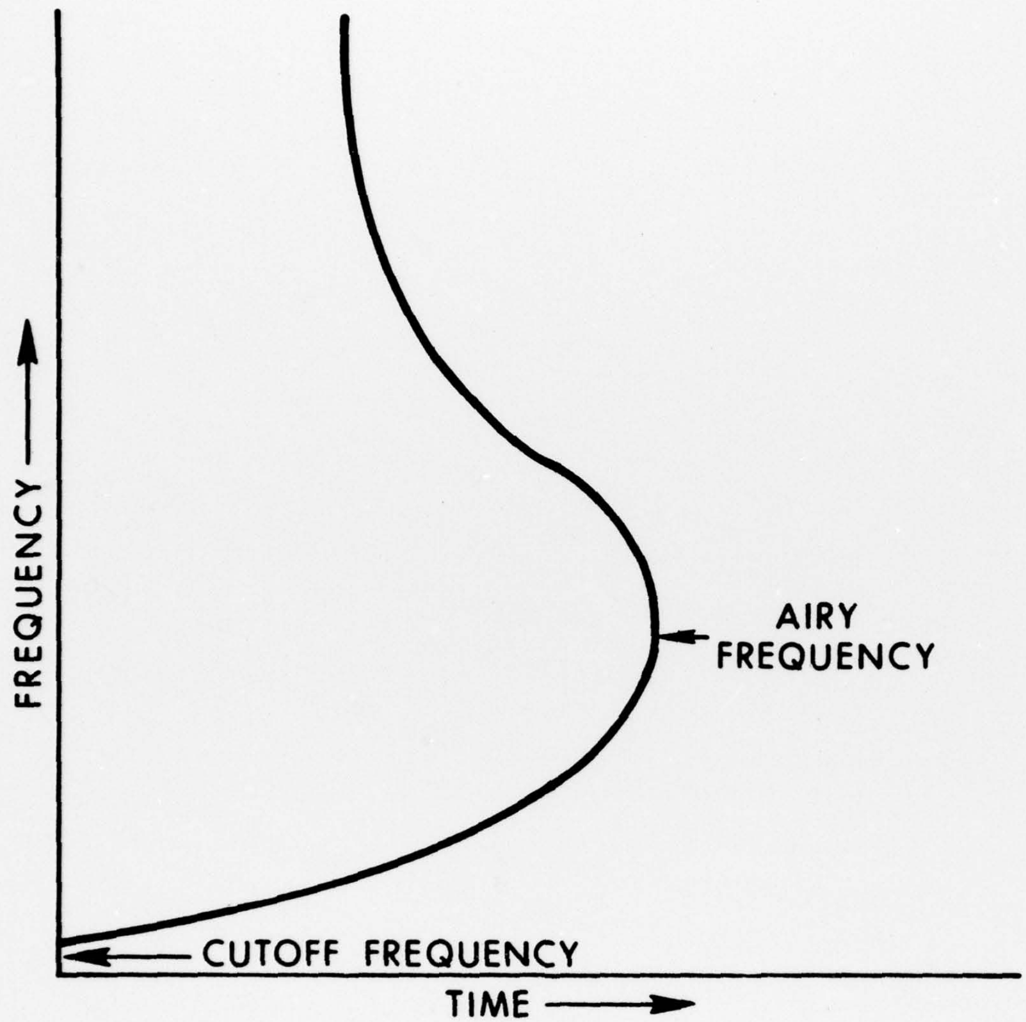


FIGURE 5

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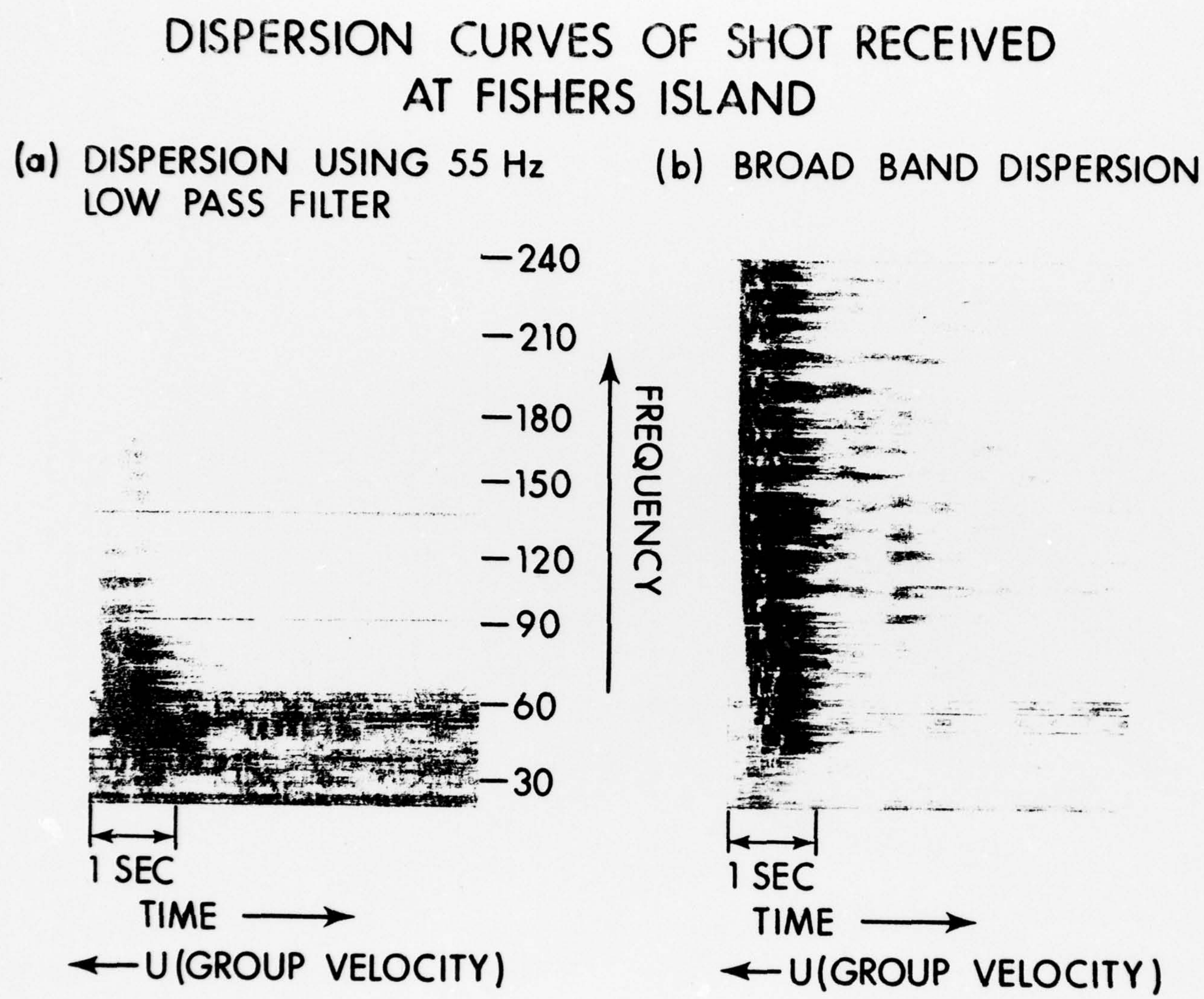


FIGURE 6

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# AMPLITUDE DISTRIBUTION AS A FUNCTION OF DEPTH

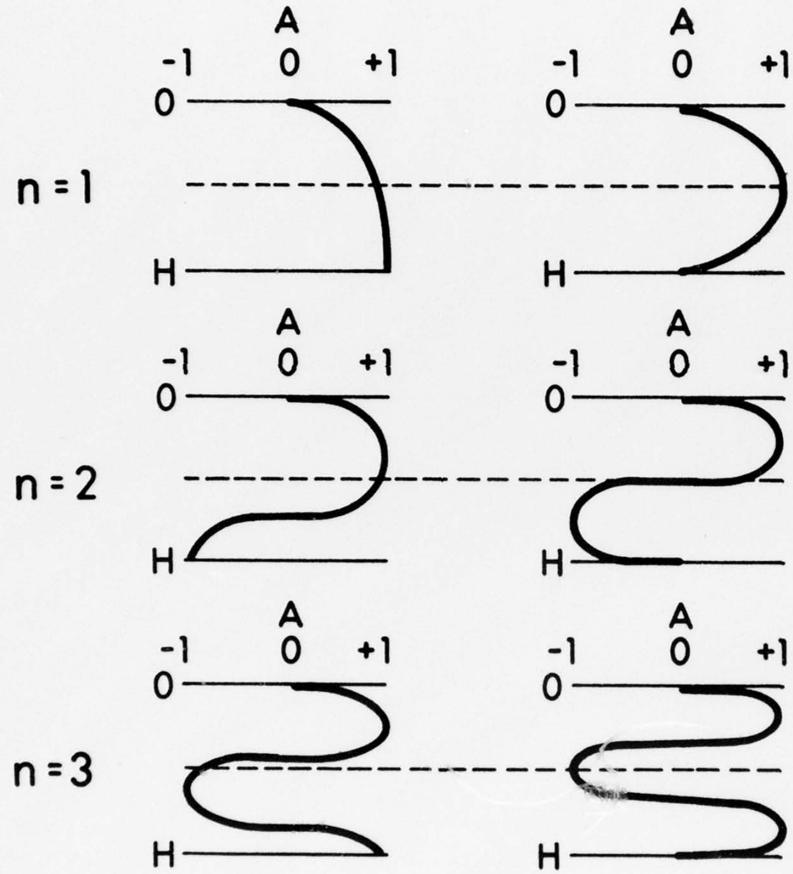


FIGURE 7

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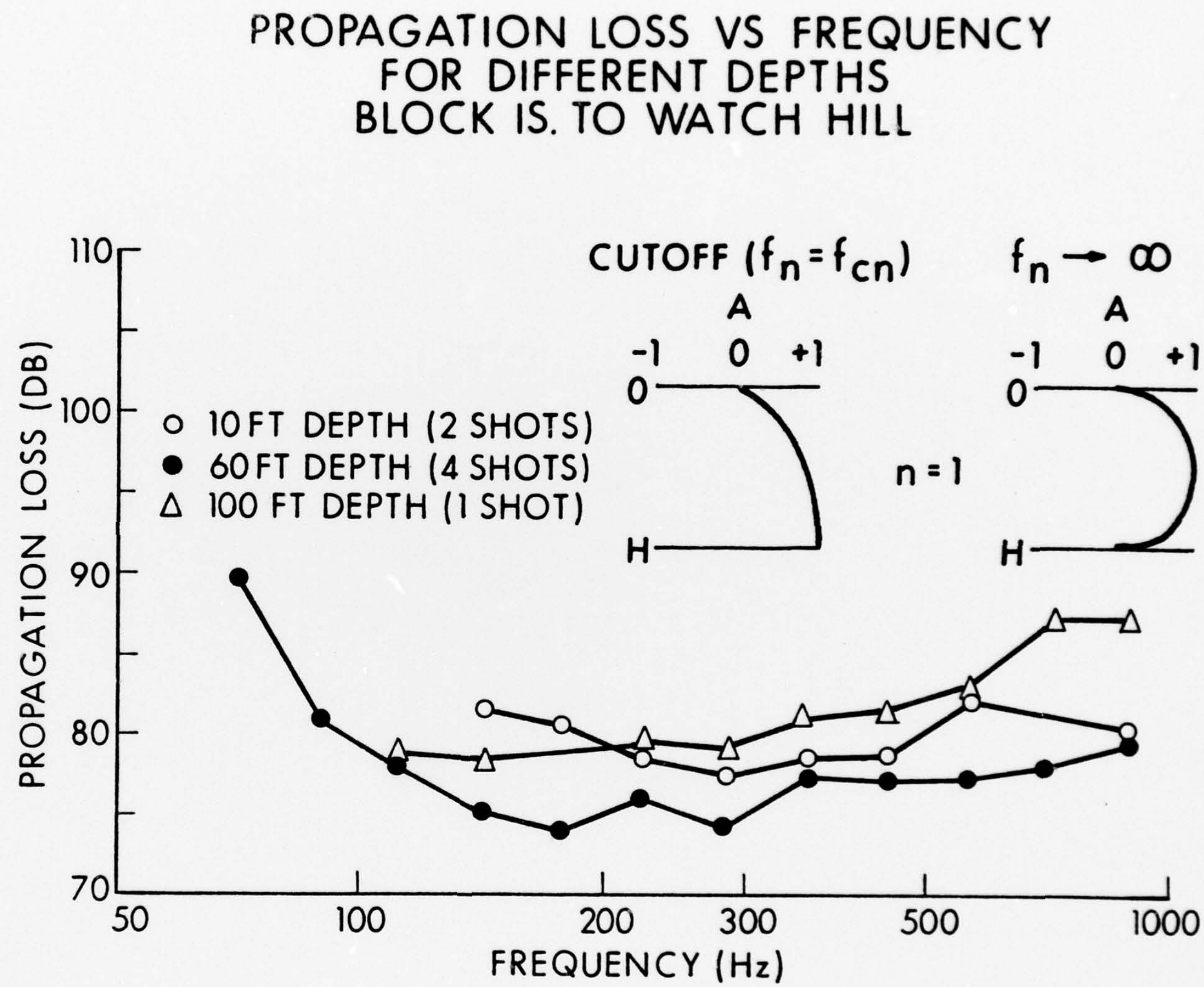


FIGURE 8

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